APPENDIX I

REPORTS AND MEMOS BY OTHERS

APPENDIX I-1

REPORT BY PROFESSOR JONATHAN BRAY: NGA GROUND MOTIONS FOR SEISMIC EVALUATION

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March 24, 2008

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Ground Motions Based on NGA for the Seismic Evaluation of the Newby Island Landfill, San Jose, California

INTRODUCTION

This report presents my recommendations regarding earthquake ground motions that are appropriate to use in the seismic evaluation of the Newby Island Landfill, which is located near San Jose, California. A draft report prepared by GeoLogic Associates that is entitled: "Geotechnical Evaluation for Proposed Vertical Expansion: Newby Island Landfill, San Jose California," dated December 2007, forms the basis of my understanding of the project. As agreed, I relied on the potential earthquake sources identified by Geologic Associates, and I was not responsible for identifying additional seismic sources including active faults that may or may not exist at or near the Newby Island Landfill.

SEISMIC HAZARD

The Newby Island Landfill is situated in one of the most seismically active areas of the world. The Geologic Associates (2007) draft report identified three primary potential earthquake sources that significantly impact the seismic hazard at this site. They are the characteristic earthquake events on the Hayward fault, on the Calaveras fault, and on the San Andreas. All other active faults that are located within 50 kilometers of the site that were identified by Geologic Associates are less critical than the Maximum Considered Earthquake (MCE) for these three sources. The MCE is also sometimes referred to as the Maximum Credible Earthquake and the Maximum Earthquake, and these terms may be considered equivalent for this report.

As is normal practice in the highly seismic regions of the San Francisco Bay and Los Angeles areas of California, deterministic MCE events will be the basis for evaluating the seismic performance of the Newby Island Landfill. The Moment Magnitude (M_w) for the Calaveras fault is lower than that for the nearby Hayward fault, so the Calaveras fault need not be considered in this MCE evaluation. However, the San Andreas fault has a MCE M_w that is significantly greater than that on the Hayward, so the San Andreas fault will be considered, although it is located further away than the Hayward fault.

The Hayward and San Andreas seismic sources were re-characterized using currently available information to estimate their maximum earthquakes and closest distances. These estimates were based on these documents:

- California Geological Survey assessment by Peterson et al. (1996)
- State of California (1982) Special Studies Zones for the Milpitas Quadrangle
- USGS (1996) Seismic Hazard Maps with Fault Parameters compiled by Barnhard and Hanson
- USGS and CGS (2006) "Quaternary fault and fold database for the United States"
- Wells and Coppersmith (1994)
- Wesnousky (1986)
- Working Group on California Earthquake Probabilities (2003)

The maximum historic earthquake on the Hayward fault is the 1868 Hayward earthquake, which was moment magnitude 6.8 to 7.0 and occurred along the Southern Hayward fault segment. The estimated recurrence interval for the Southern Hayward fault source with a mean magnitude of 6.8 is 290 years. Rupture along the entire Hayward fault could lead to a moment magnitude 7.1 event. This larger event would like have a recurrence interval on the order of 500 years. With this information in mind, the MCE for the Hayward fault is judged to be $M_w = 7.1$. The current fault database places the Hayward fault at a closest site-to-source distance (R) of 6 km from the Newby Island landfill. However, the site is located approximately 3.3 km from the Hayward fault using the closest distance from the site to the Southern Hayward fault (as delineated on the Milpitas Quadrangle Special Studies Zones map). Using this more detailed information on the Southern Hayward fault segment, the closest distance from the Hayward fault to the site is judged to be 3.3 km. In summary, the MCE on the Hayward fault is $M_w = 7.1$ at a site-to-source distance of 3.3 km.

The MCE for a repeat of a 1906-type event on the San Andreas fault is $M_w = 7.9$. The site is located approximately 24 km from the San Andreas fault, and the estimated recurrence interval for this event is approximately 380 years. In summary, the MCE on the San Andreas fault is $M_w = 7.9$ at a site-to-source distance of 24 km.

Due to its close proximity to the project site and its large magnitude, the Hayward fault MCE scenario is likely the most important earthquake event for this project. Seismic sources at greater distances would only be important for this project if they generated larger magnitude earthquakes or were significantly more likely to occur. A repeat of the 1906 event on the San Andreas fault could generate a larger magnitude event, which would produce ground motions with longer durations of strong shaking and significantly different frequency content. Hence, this event was also considered initially as possibly controlling some aspects of the seismic performance of the Newby Island Landfill.

In addition to this deterministic MCE assessment of the seismic sources, the USGS web site for the National Seismic Hazard Mapping Project (http://earthquake.usgs.gov/research/hazmaps/) was consulted to develop a simplified Probabilistic Seismic Hazard Assessment (PSHA) at the Newby Landfill site (GPS coordinates: N37.458 W121.94) to aid in the development of a suite of acceleration-time histories. PSHA provides useful insight regarding a deterministic analysis. Through de-aggregation of the seismic hazard at the site, it was found that the Hayward fault contributes most significantly to the ground shaking hazard for both frequent and rare events at both short and long periods (at least 50% for the 475 and 975 year return period levels). The Hayward fault scenario dominates the ground shaking hazard at this site. The San Andreas fault contributes only somewhat to the seismic hazard at long periods (> 1 s) at this site (i.e., about 20% of the seismic hazard for the 475 year return period spectral acceleration at a period of 2 seconds).

DESIGN ACCELERATION RESPONSE SPECTRUM

Acceleration response spectra (at 5% damping) were developed for hypothetical "outcropping rock" site conditions for the MCE events for the Hayward and San Andreas faults using the Next Generation Attenuation (NGA) ground motion relationships. The NGA relationships were developed through a well-documented consensus research effort by five of the most respected teams of ground motion experts (PEER 2008). The NGA relationships are considered to represent the best scientific understanding of ground motion attenuation based on empirical data for shallow crustal earthquakes along active plate margins (i.e., California-type earthquakes). They have been adopted by the USGS in the development of the Nation's seismic hazard maps and used on critical, high profile projects such as the BART Earthquake Safety Program. All five NGA relationships were used in this study (i.e., Abrahamson, and Silva 2007, Boore and Atkinson 2007, Campbell and Bozorgnia 2007, Chiou and Youngs 2006, and Idriss 2007). The input parameters used in the NGA relationships are shown in Table 1. The spectra estimated by each of these attenuation relationships were then averaged to develop the average spectra (without near-fault effects) for the MCE for each fault.

The average spectrum for the nearby Hayward MCE scenario was also modified as recommended by Abrahamson (2000) using a modification of the Somerville et al. (1997) procedure to capture the average effects of forward-directivity for a rupture that would initiate well north of the site and propagate southward. The forward-directivity input parameter for the Hayward strike-slip fault rupture event to the Abrahamson (2000) model, which uses modified Somerville et al. (1997) model coefficients, is $X \cos(\varphi) = 0.94 \leq 0.4$. Note that it is just as likely for the rupture to propagate away from the site (i.e., backwards-directivity) as it is for it to propagate towards the site (i.e., forward-directivity), so each can be considered as realistic cases for the MCE event on the Hayward fault. However, the selection of ground motions will be biased for forward-directivity effects, because they are typically more severe. This decision increases the conservatism of the design spectrum, but this is consistent with the current state-of-the-practice in California.

The average median, 16^{th}, and 84^{th} percentile acceleration response spectra for the MCE for the Hayward and San Andreas faults are shown on Figure 1. The Hayward fault MCE scenario has an average median peak ground acceleration (PGA) of 0.42 g, and the San Andreas fault MCE scenario has a median PGA of only 0.18 g.

In addition to PGA, spectral accelerations at other periods are also important. Based on the critical landfill cross sections that Geologic Associates identified, potential sliding masses within the Newby Island Landfill vary between heights of 50 and 200 feet. Using average shear wave velocities of California landfills from Kavazanjian et al. (1996) and typical shear wave velocities of soil materials, the initial fundamental period of potential sliding masses within this landfill range between 0.3 s and 1 s (Bray et al. 1998). Deep soil deposits underlie the landfill to a depth of bedrock greater than 1000 feet so that there is the possibility for significant amplification of ground shaking through the deep foundation soils and overlying solid-waste material over the period range of 0.3 s to 1.5 s (also includes the effects of soil and waste softening during intense shaking due to material nonlinearity). Ground motions should be selected so that they capture the target spectra for each MCE scenario across the period range of 0.3 s to 1.5 s as well as have reasonable PGA values.

Other important ground motion parameters, namely significant duration (as defined by Trifunac and Brady, 1975) and mean period (as defined by Rathje et al., 1998), were estimated for these scenarios using the relationships proposed by Abrahamson and Silva (1996) and Rathje et al. (2004), respectively. The Hayward fault MCE scenario has a median PGA value of 0.42 g, a median mean period value of 0.45 s, and a median significant duration of 15 s. For the forward-directivity near-fault ground motion, which is one possible realization for the Hayward fault MCE scenario, the peak ground velocity (PGV) would be on the order of 90 cm/s (Bray and Rodriguez-Marek, 2004). The San Andreas fault MCE scenario has a median PGA value of 0.18 g, a median mean period value of 0.6 s, and a median significant duration of 32 s.

Examination of the spectra shown in Figure 1 indicates that the controlling event for this site is the MCE (with forward-directivity) on the Hayward fault. Preliminary dynamic analyses performed by Geologic Associates engineers using acceleration-time histories matched to the average median acceleration response spectra for the MCE for the Hayward fault produced significant higher surface PGAs and calculated larger seismically induced permanent displacements than those for the San Andreas fault MCE. Therefore, the controlling deterministic event for performing the seismic evaluation of the Newby Island Landfill is the MCE Hayward fault event with $M_w = 7.1$ at a site-to-source distance of 3.3 km with forward-directivity.

EARTHQUAKE GROUND MOTIONS

Seven acceleration-time histories were selected to represent the seismic hazard for "outcropping rock" at the site in the context of evaluating liquefaction potential of sandy soils and calculating seismically induced permanent displacements. The number of time histories (i.e., 7) is consistent with that specified in the 1997 Uniform Building Code for time history analyses and greater than the minimum number of time histories required by the ASCE 7-05 guidance document (i.e., 5). The use of seven time histories is also consistent with the number of time histories commonly used in seismic analysis of important projects (e.g., hospital design, BART earthquake retrofit project, and several Bay Area landfills).

Some (but not all) of the time histories selected to capture the Hayward fault MCE scenario should match the design acceleration spectrum that has been modified to account for forward-directivity. It is just as likely for the rupture to propagate away from the site (i.e., backwards-directivity) as it is for it to propagate towards the site (i.e., forward-directivity), so each should be considered as realistic cases for the MCE event on the Hayward fault. Additionally, most of the critical slopes at the Newby Island Landfill are oriented parallel to the strike of the Hayward fault as opposed to normal to its strike. Hence, both fault-normal and fault-parallel components of forward-directivity motions as well as neutral-directivity and backward-directivity motions were considered representative of the type of ground motions possible at this site. The selection of ground motions, however, will be biased for forward-directivity effects, because they typically represent a more severe loading for landfills.

The ground motions were selected from the available database of ground motions (i.e., Pacific Earthquake Engineering Research Center database developed by Dr. Walt Silva of Pacific Engineering Analysis) based on tectonic environment, distance, magnitude, fault type, site conditions, and other factors (such as near-fault forward-directivity). To supplement the lack of empirical data for large magnitude events at close distance to a ruptured fault, a synthetic "rock" motion developed by Dr. Norm Abrahamson to represent a near-fault motion for a magnitude 7 event for the Coronado Bridge was used for the Hayward fault MCE scenario. Selected recorded or synthetic ground acceleration-time histories were modified with amplitude scaling factors of 0.8 to 2.0, except for one record that was scaled by a factor of 0.4 and another record that was scaled by a factor of 3.7, to better capture the design spectrum for the MCE event.

The key characteristics of the selected suite of earthquake ground motions are provided in Table 2. The acceleration response spectra for the selected suite of Hayward fault MCE scenario motions are shown in Figure 2 with the MCE design acceleration response spectra for this scenario with and without forward directivity effects. Other important ground motion parameters include mean period, which was estimated to be 0.45 s, and significant duration, which was estimated to be 15 s.

The seven acceleration-time histories selected for the MCE event on the Hayward fault with forward-directivity capture its design spectrum well as shown in Figure 2. The average of the seven spectra "matches" the design spectrum over the period range of interest (i.e., 0.3 s to 1.5 s) reasonably well, and their average PGA of 0.42 g is reasonable. Additionally, the durations of these motions are appropriate for the moment magnitudes of the controlling earthquake event, with consideration of rupture directivity.

Three of the selected motions are the intense fault-normal components of the forward-directivity motions (i.e., Coronado, Lucerne, and Pacoima Dam). The Gebze motion is the fault-parallel component motion of a forward-directivity motion, and the Izmit is a fault-normal component of a neutral-directivity motion. The longer duration Hayward City Hall motion was scaled by intensity to give a backward-directivity type response, and the Sahop Casa Flores motion represents an "ordinary" ground motion that was recorded in the near-fault region (i.e., distance < 10 km).

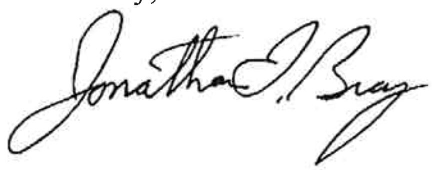
Acceleration, velocity, and displacement-time histories of these motions with each individual acceleration response spectrum at 5% damping are shown in Figures 3 to 9. The selected acceleration-time histories have been provided as digital files that can be used directly without modification in your seismic stability analyses (i.e., do not scale them to match the median PGA, as they capture the important aspects of the ground motions "as is" with reasonable variations).

CLOSURE

I hope that you find this information of use in your seismic evaluation of the Newby Island Landfill. The objective of my study was to provide acceleration-time histories that could be used in a seismic evaluation of the Newby Island Landfill in San Jose, California. Evaluation of other seismic hazards, including liquefaction of silty and sandy soils and cyclic strength loss of soft clay, and nonseismic design issues were not part of the scope of this study.

Please contact me by telephone at (925) 212-7842 if you require additional information. Thank you.

Sincerely,



Jonathan D. Bray, Ph.D., P.E.

ATTACHMENTS:
References
Tables 1-2
Figures 1-9
Digital Files of Acceleration-Time Histories

REFERENCES

Abrahamson, N.A. (2000) "Effects of Rupture Directivity on Probabilistic Seismic Hazard Analysis," Proc. Sixth International Conference on Seismic Zonation, Palm Springs, CA, Nov. 12-15.

Abrahamson, N.A. and Silva, W.J., (1996) "Empirical Ground Motion Models," Report Prepared for Brookhaven National Laboratory, USA.

Abrahamson, N. A., and Silva, W. (2007) "Abrahamson & Silva NGA Ground Motion Relations for the Geometric Mean Horizontal Component of Peak and Spectral Ground Motion Parameters", as posted on the PEER website.

ASCE (2005) "Minimum Design Loads for Buildings and Other Structures," ASCE Standard - ASCE/SEI 7-05, Including Supplement, No. 1, ASCE, Reston, VA.

Boore, D. M., and Atkinson, G. M. (2007) "Boore-Atkinson NGA Ground Motion Relations for the Geometric Mean Horizontal Component of Peak and Spectral Ground Motion Parameters", PEER Report *2007/01,* Pacific Earthquake Engineering Research Center, College of Engineering, University of California, Berkeley, May.

Bray, J. D., Rathje, E. M., Augello, A. J., and Merry, S. M. (1998) "Simplified Seismic Design Procedure for Lined Solid-Waste Landfills," *Geosynthetics International Journal,* Vol. 5, Nos. 1-2, pp. 203-235.

Bray, J.D. and Rodriguez-Marek, A. (2004) "Characterization of forward-directivity ground motions in the near-fault region," *Soil Dynamics and Earthquake Engineering,* V. 24(11), Dec., pp. 815-828.

California Department of Conservation (1996) Division of Mines and Geology DMG Note 49: GUIDELINES FOR EVALUATING THE HAZARD OF SURFACE FAULT RUPTURE.

Campbell, K.W., and Bozorgnia, Y. (2007) "Campbell-Bozorgnia NGA Ground Motion Relations for the Geometric Mean Horizontal Component of Peak and Spectral Ground Motion Parameters". PEER Report *2007/02,* Pacific Earthquake Engineering Research Center, College of Engineering, University of California, Berkeley, May.

Chiou, B., and Youngs. R. R. (2006), "Chiou and Youngs PEER-NGA Empirical Ground Motion Model for the Average Horizontal Component of Peak Acceleration and PseudoSpectral Acceleration for Spectral periods of 0.01 to 10 seconds", PEER website.

Idriss, I. M. (2007), "Empirical Model for Estimating the Average Horizontal Values of Pseudo-Absolute Spectral Accelerations Generated by Crustal Earthquakes, Volume I, Sites with V_{s30}=450 to 900 *m/sec",* PEER website.

International Conference of Building Officials (1997) "Uniform Building Code: Volume 2 - Structural Engineering Design Provisions," Chap. 16, Div. IV - Earthquake Design, pp. 2-9 through 2-38.

Kavazanjian, Jr., E., Matasovic, N., Stokoe, K. H., and Bray, J. D. (1996) "In Situ Shear Wave Velocity of Solid Waste From Surface Wave Measurements," *Proceedings of the Second International Congress on Environmental Geotechnics*, Osaka, Japan, Nov. 5-8, Vol. 1, pp. 97-102.

PEER (2008) "Next Generation Attenuation of Ground Motions (NGA) Project," Pacific Earthquake Engineering Center, web site: http://peer.berkeley.edu/products/nga_project.html

Peterson, M. D., Bryant, W. A., Cramer, C.H., Cao, T., Reichle, M., Frankel, A., Lienkaemper, J.J., McCrory, P.A., and Schwartz, D. P. (1996) "Probabilistic Seismic Hazard Assessment for the State of California," California Department of Conservation, Division of Mines and Geology Open-File Report 96-08, USGS Open-File Report 96-706.

Rathje, E.R., Abrahamson, N.A. and Bray J.D. (1998) "Simplified Frequency Content Estimates Of Earthquake Ground Motions," Journal of Geotechnical and Geoenvironmental Engineering, American Society of Civil Engineers, Vol. 124, No. 2, pp. 150-159.

Rathje, E.M., Faraj, F., Russell, S., and Bray, J.D. (2004) "Empirical Relationships for Frequency Content Parameters of Earthquake Ground Motions," *Earthquake Spectra*, Earthquake Engineering Research Institute, Vol. 20 (1), Feb., pp. 119-144.

State of California (1982) Special Studies Zones for the Milpitas Quadrangle.

Trifunac, M.D. and Brady, A.G. (1975) "A Study of the Duration of Strong Earthquake Ground Motion," Bulletin of the Seismological Society of America, **65**: 581-626.

U.S. Geological Survey (1996) "National Seismic Hazard Mapping Project," Earthquake Hazards Program with Fault Parameters compiled by Ted Barnhard and Stan Hanson, web site address: <http://geohazards.cr.usgs.gov/>.

U.S. Geological Survey and California Geological Survey (2006) "Quaternary fault and fold database for the United States," accessed March 2006 from USGS web site: <http//earthquakes.usgs.gov/regional/qfaults/>.

Wells, D.L. and Coppersmith, K.J. (1994) New Empirical Relationships among Magnitude, Rupture Length, Rupture Width, Rupture Area, and Surface Displacement. BSSA, Vol. 84, No.4, pp 974-1002.

Wesnousky, S.G. (1986) Earthquakes, Quaternary faults, and seismic hazard in California: Journal of Geophysical Research, v. 91, p. 12, 587-12, 631.

Working Group on California Earthquake Probabilities (2003) "Earthquake Probabilities in the San Francisco Bay Region: 2002-2031," U.S. Geological Survey Open-File Report 03-214.

Table I: NGA Attenuation Relationships Input Parameters

Source Parameters	Hayward MCE	San Andreas MCE
Magnitude	7.1	7.9
Top of Rupture (km)[1]	0	0
Fault Type	strike-slip	strike-slip
Dip (degrees)	90	90
Rupture Width (km)	15	15
Distance (location) Parameters[1]		
R_{rup} (km)	3.3	24
R_{jb} (km)	3.3	24
Site Response Parameters		
V_{S30} (m/s)[2]	900	900
$Z_{1.0}$ (km)[3]	0.015	0.015
$Z_{2.5}$ (km)[4]	0.6	0.6

Notes

1 Rupture is assumed to extend to the surface.

2 V_{S30} for "outcropping rock" at site is estimated to be 2950 fps (900 m/s).

3 Depth to layer with shear wave velocity of 1.0 km/sec is estimated based on the subsurface profile provided by Geologic Associates and information from the Bay Area seismic model. As a point of reference, when the depth to the 1.0 km/sec is unknown, Abrahamson and Silva (2007) recommend using a value of 0.016 km and Chiou and Youngs (2006) recommend using a value of 0.012 km.

4 Depth to the layer with shear wave velocity of 2.5 km/s is estimated based on the subsurface profile provided by Geologic Associates and information from the Bay Area seismic model. As a point of reference, NGA providers suggest that a median estimate of this value given $Z_{1.0}$ = 0.015 km is about 0.57 km.

Table 2. Characteristics of selected modified suite of earthquake rock input ground motions

Ground Motion Record & Event	Designation	T_m (s)	$D_{5\text{-}95}$ (s)	PGA (g)	PGV (cm/s)	Arias Intensity (m/s)
Coronado (Strike-Normal) - Synthetic	coronfn_56	0.51	10.48	0.50	36.44	2.30
Sahop Casa Flores_270 - Imperial Valley EQ (1979)	H_SHP270	0.33	7.47	0.61	37.15	3.94
Izmit_180 - Kocaeli, Turkey EQ (1999)	izt180_3	0.62	14.99	0.30	45.20	2.25
Lucerne_260 - Landers EQ (1992)	lcn260	0.33	13.14	0.58	117.23	4.46
Pacoima Dam_194 (upper left) – Northridge EQ (1994)	Pacoima_UL_194	0.44	5.96	0.51	41.42	1.38
Hayward City Hall (334) - Loma Prieta EQ (1989)	HaywardCHGN_334	0.37	15.40	0.19	20.98	0.55
Gebze (270) – Kocaeli, Turkey EQ (1999)	Gebze_270	0.59	7.66	0.21	44.54	0.72

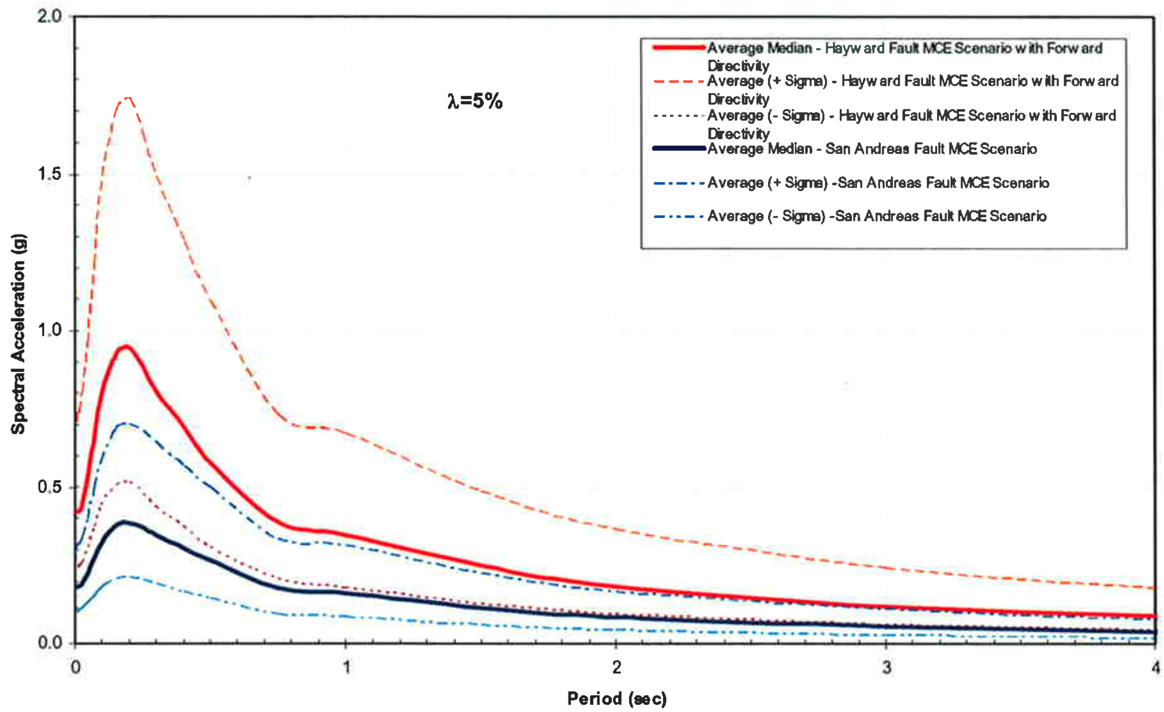


FIG. 1. The Average Median, 16th, and 84th Percentile Acceleration Response Spectra (5% damped) for the Maximum Considered Earthquake (MCE) for the Hayward fault (M_w = 7.1 at R = 3.3 km with forward-directivity) and the San Andreas fault (M_w = 7.9 at R = 24 km).

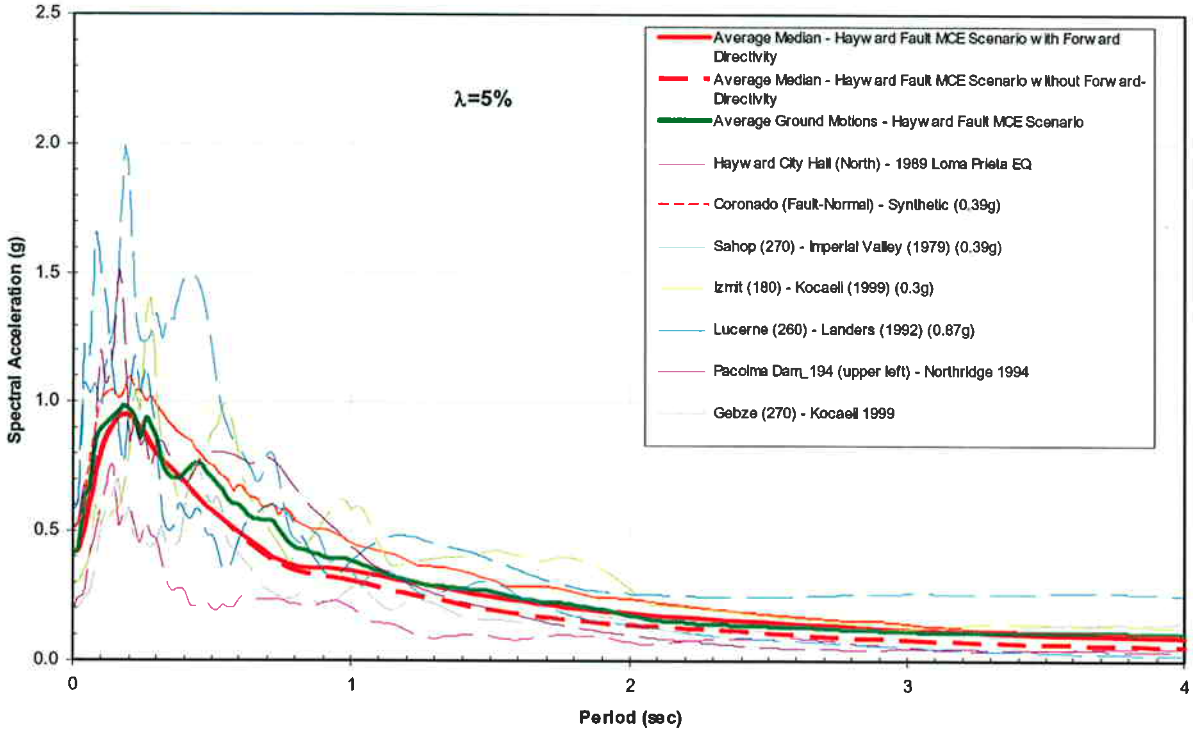


FIG. 2. Acceleration Response Spectra for Ground Motions Selected for the Hayward Fault MCE Scenario with Its Median Design Spectra with and without Forward-Directivity.

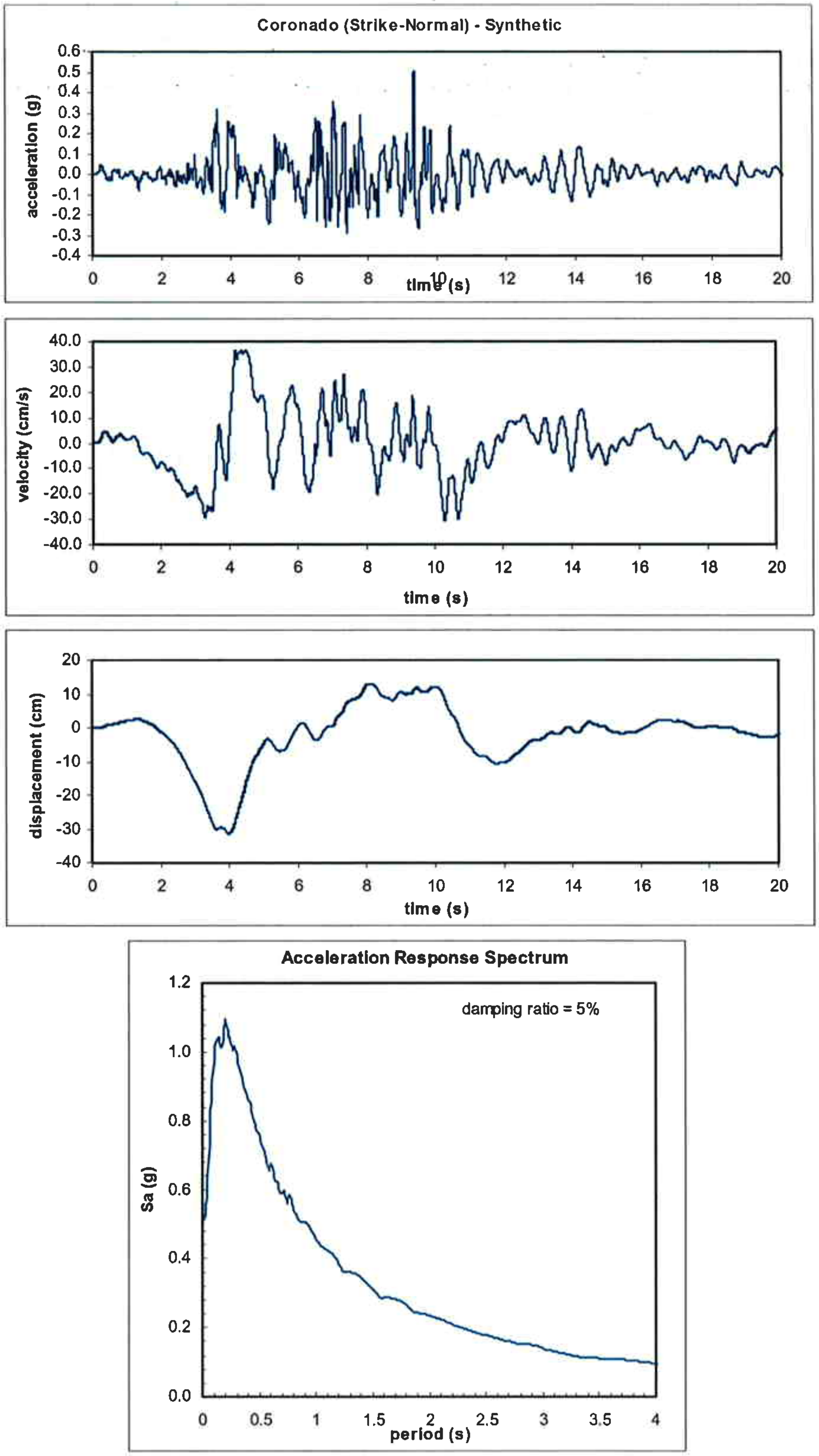


FIG. 3. Modified Synthetic Coronado Fault-Normal Motion

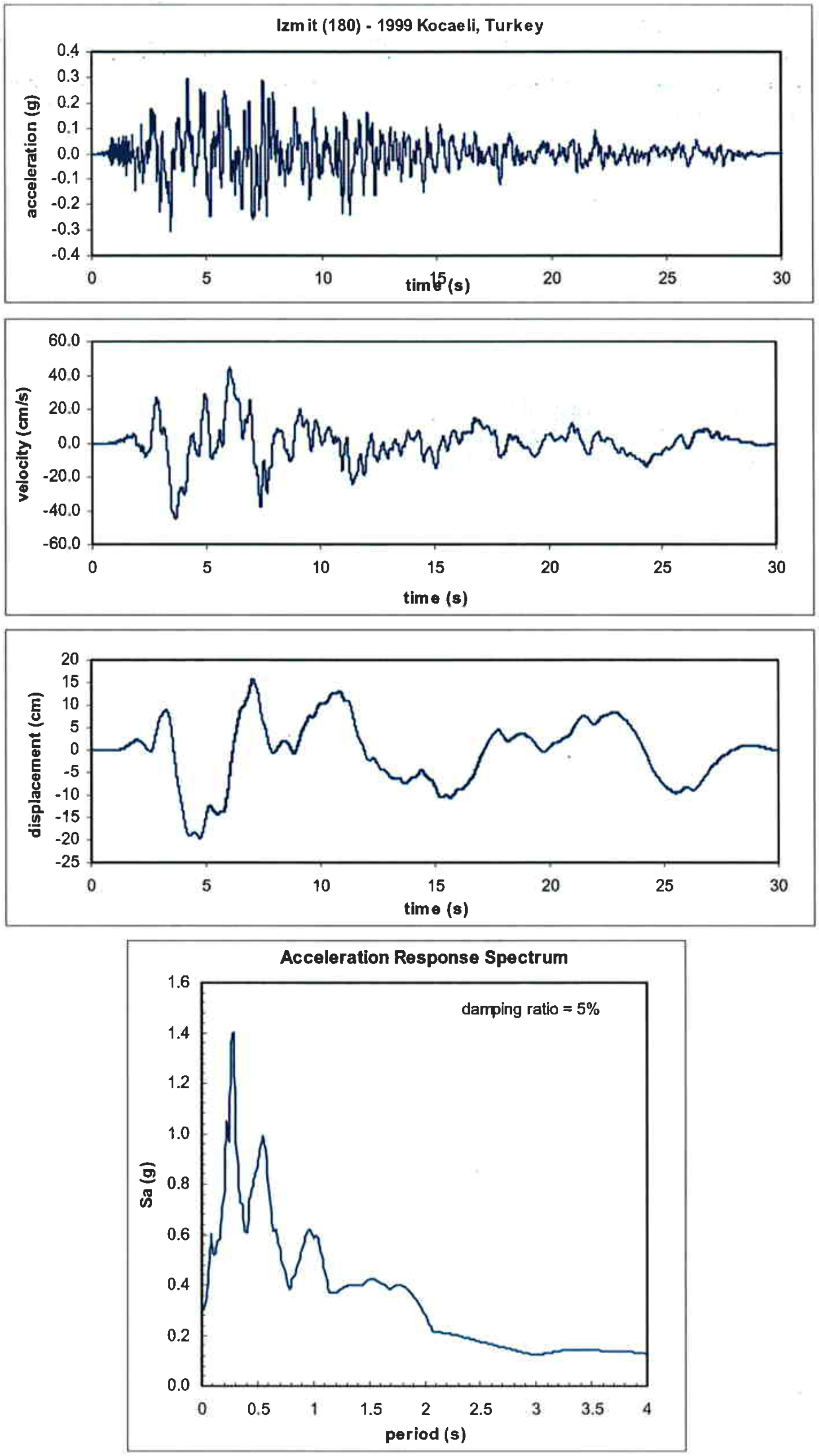


FIG. 4. Modified Izmit (180) record from the 1999 Kocaeli, Turkey Earthquake

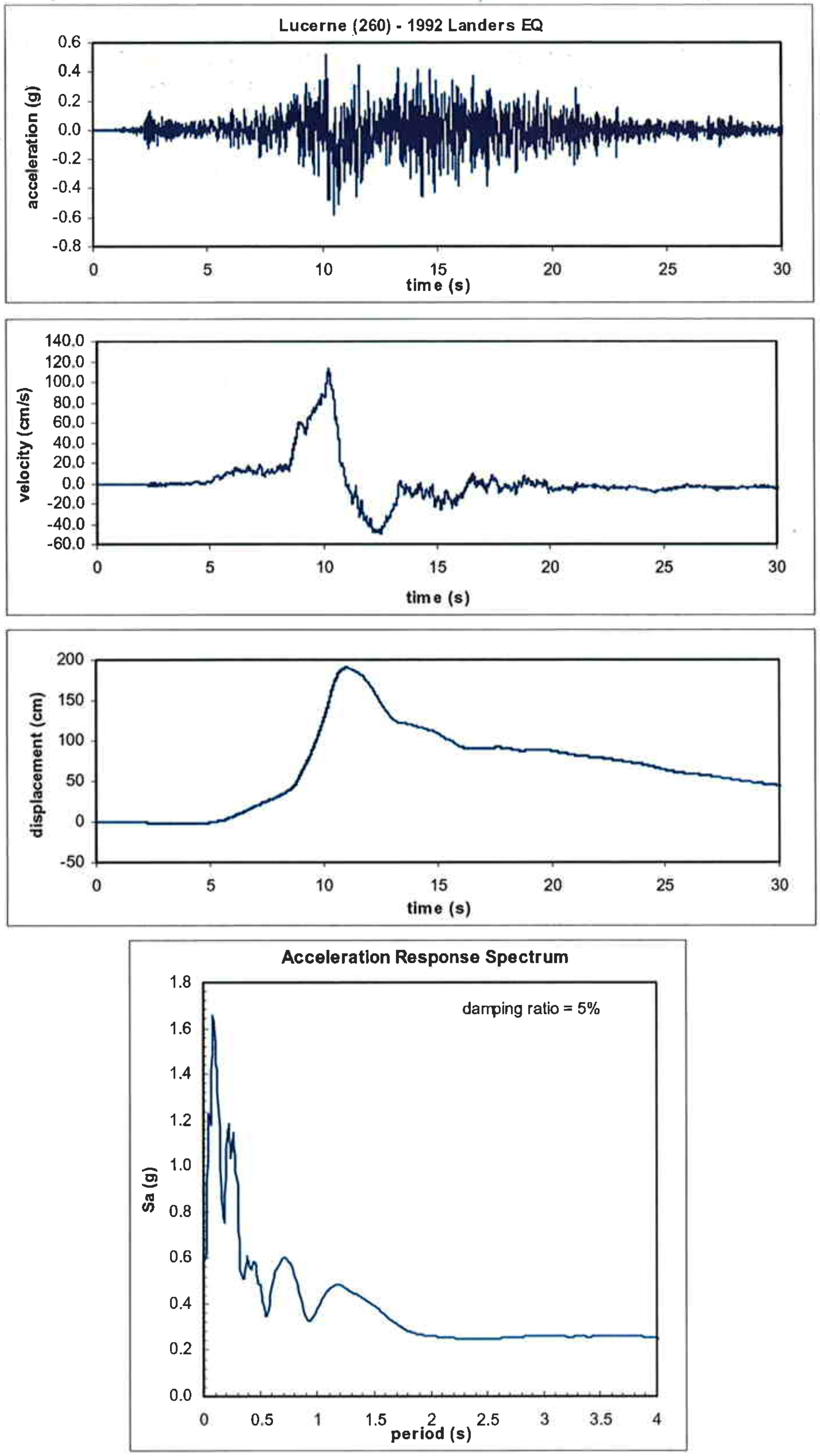


FIG. 5. Modified Lucerne (260) record from the 1992 Landers Earthquake

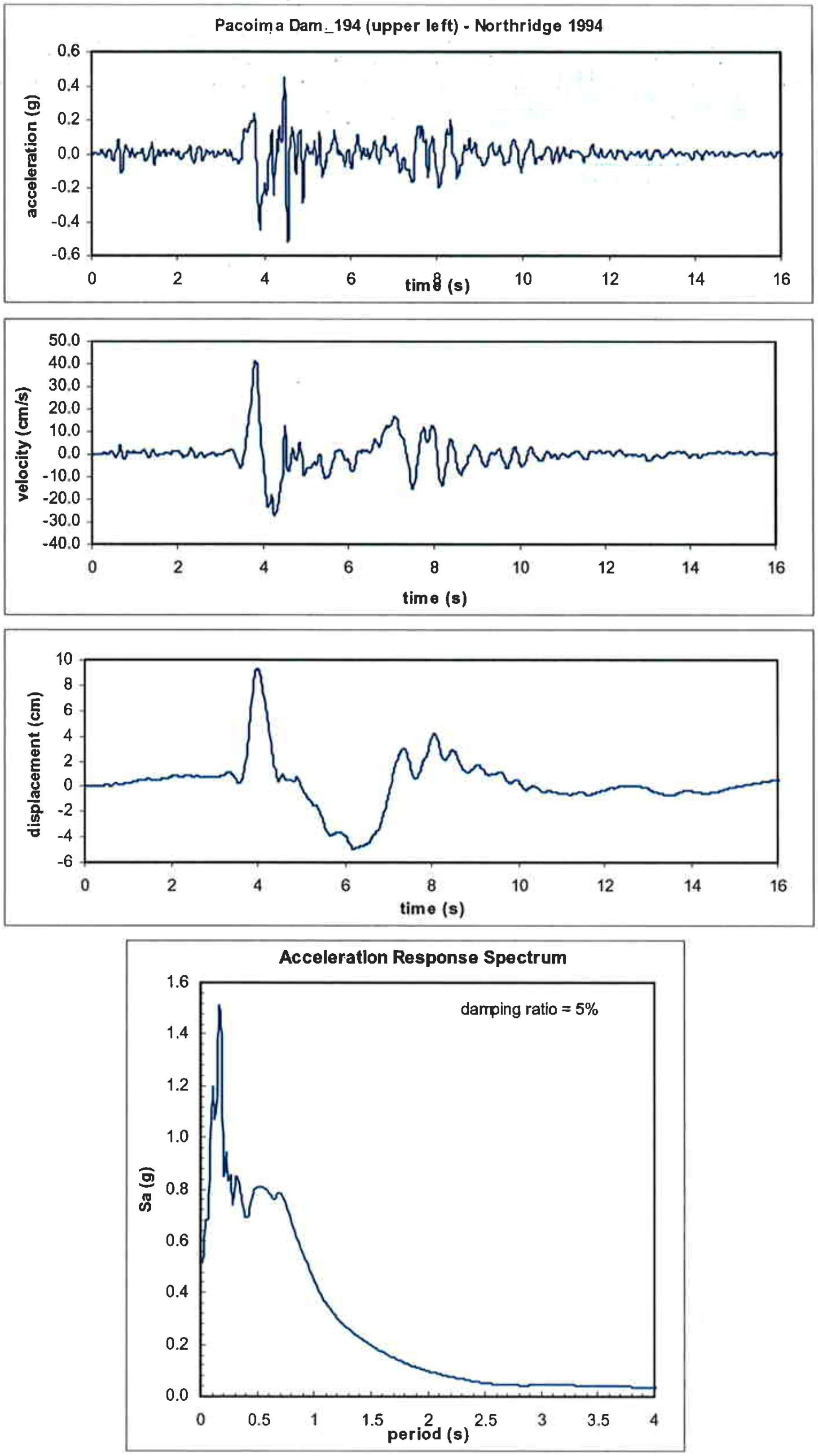


FIG. 6. Modified Pacoima Dam (upper left, 194) record from the 1994 Northridge Earthquake

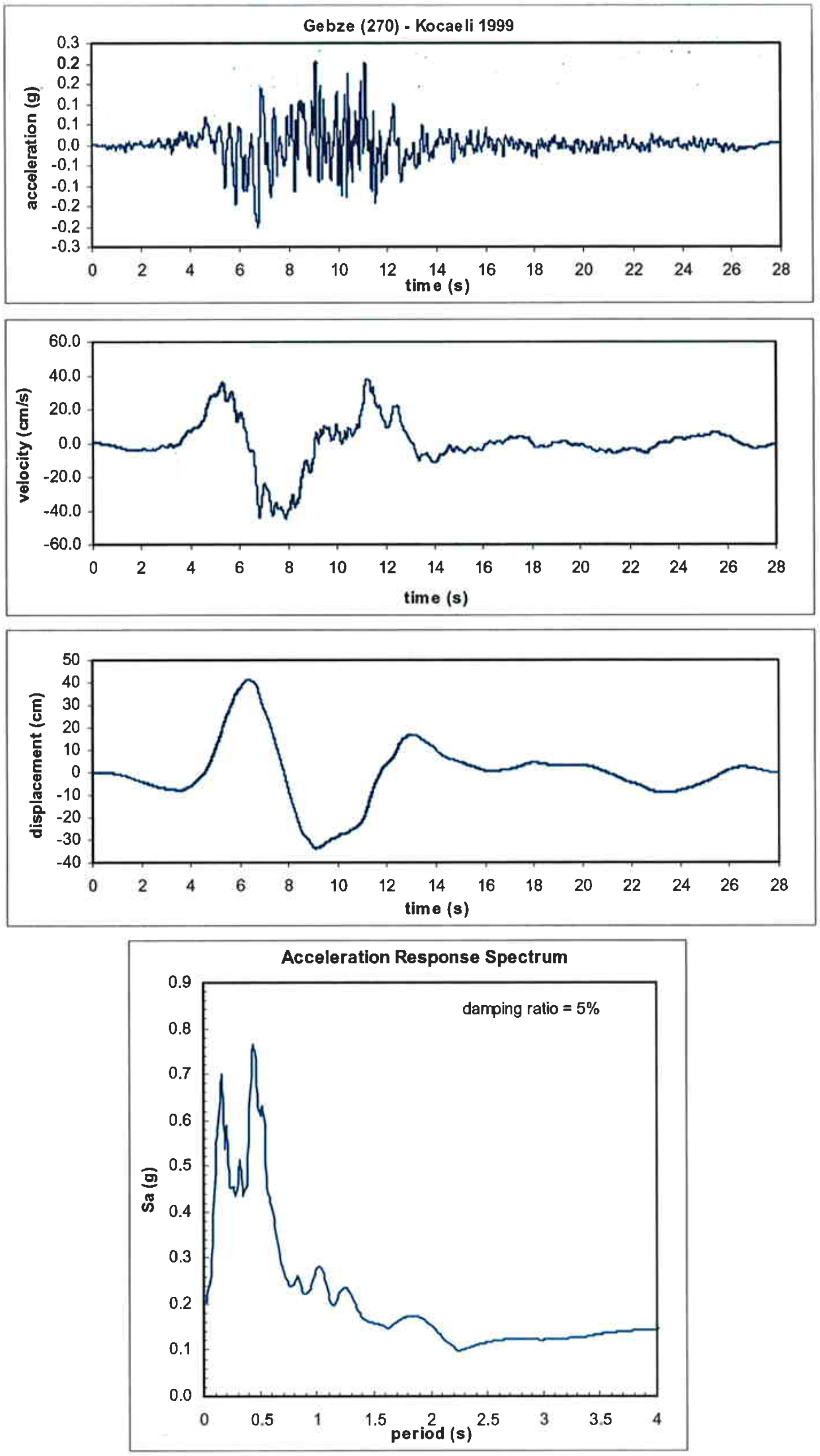


FIG. 7. Modified Gebze (270) record from the 1999 Kocaeli, Turkey Earthquake

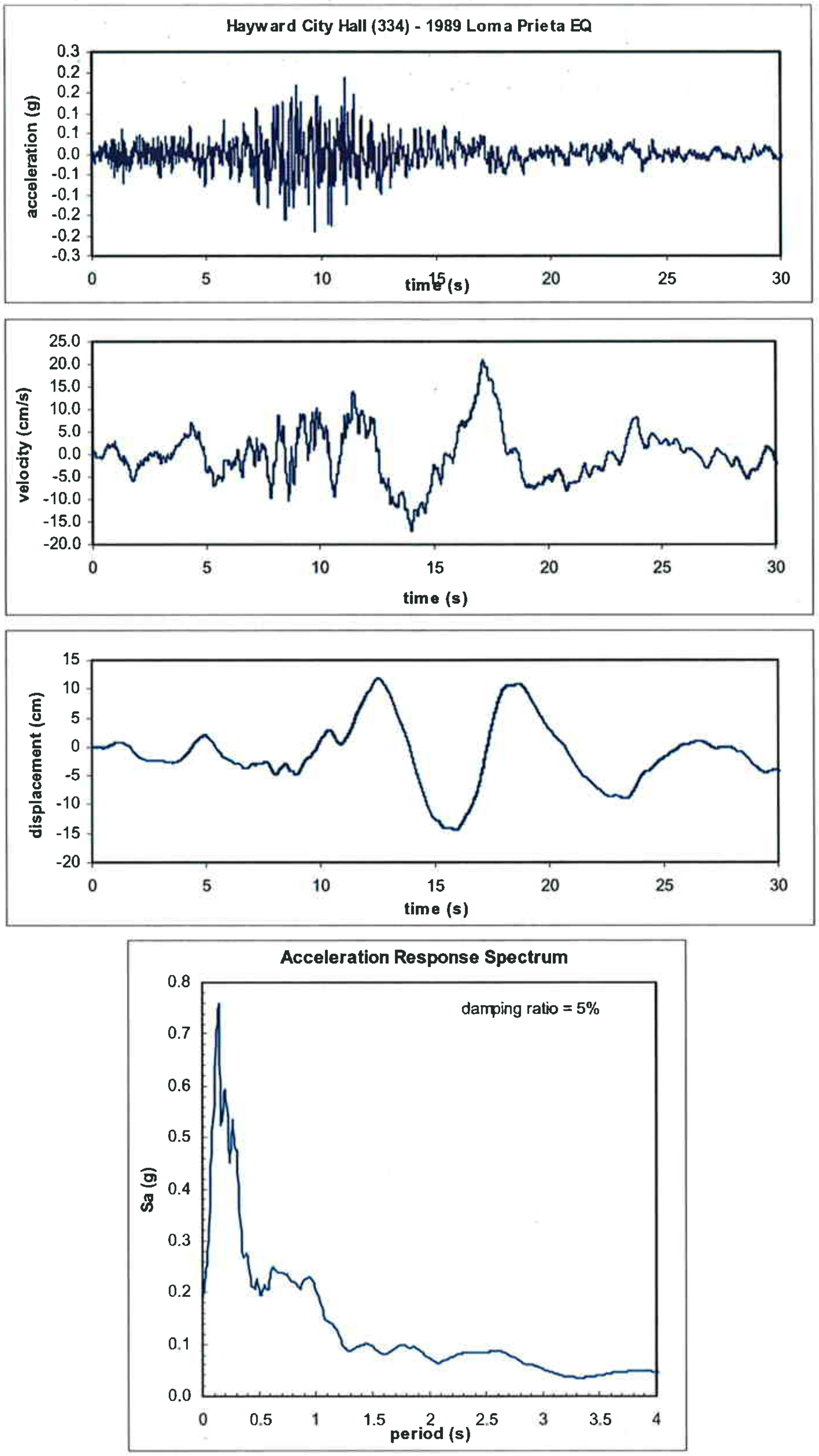


FIG. 8. Modified Hayward City Hall (334) record from the 1989 Loma Prieta Earthquake

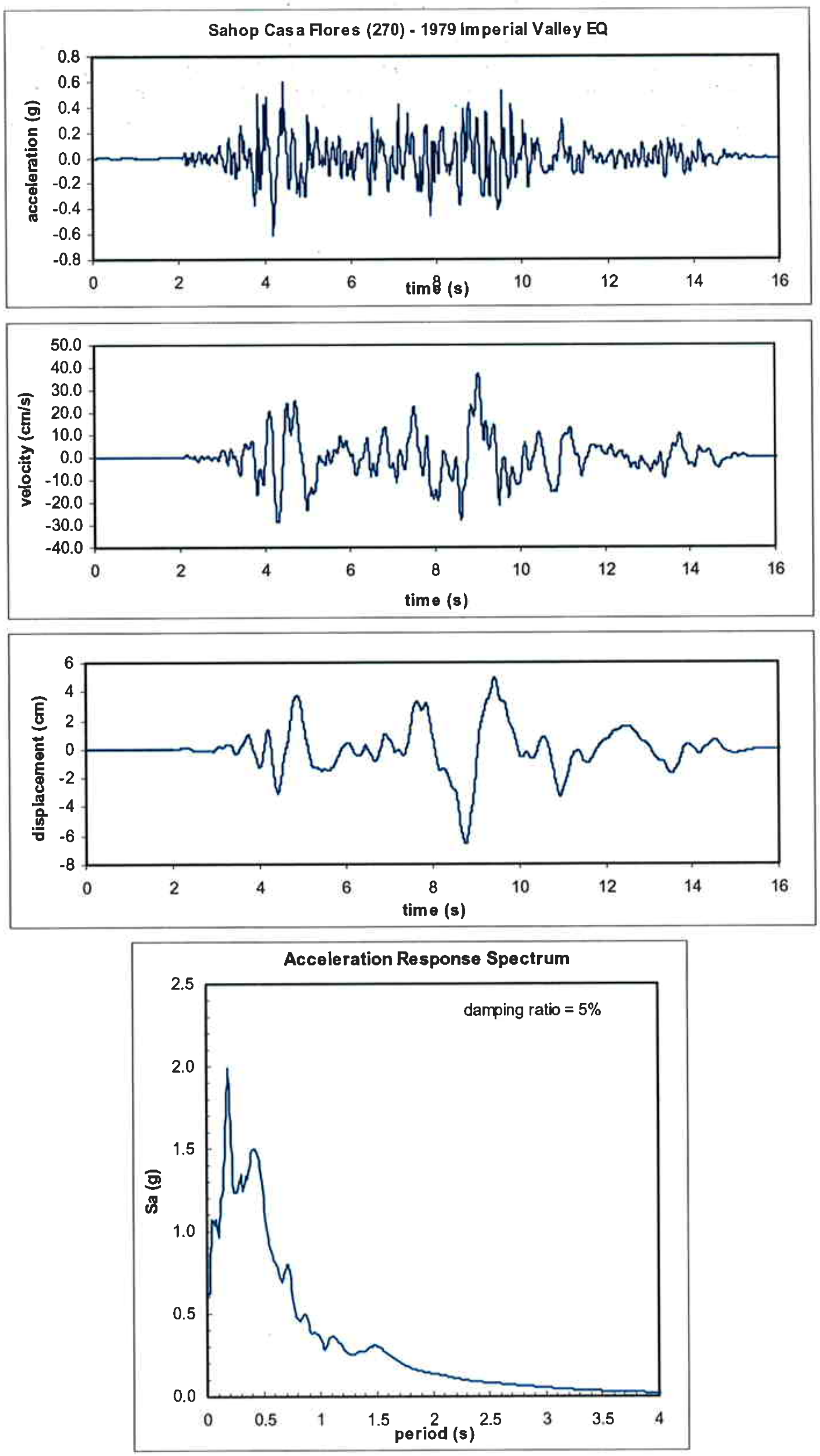


FIG. 9. Modified Sahop Casa Flores (270) record from the 1979 Imperial Valley Earthquake